Ozone Patterns for the Lower Peninsula of Michigan

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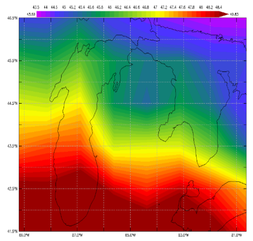
Introduction

Ozone, which has the chemical form O_3, is a greenhouse gas and a health hazard to sensitive populations which include children, people with lung disease or asthma[5]. Studies from the last few years have shown a correlation of high ozone levels (regardless of other pollutants) with inflammation and heart rhythm disturbances[2].

FIGURE 1

Ozone is formed in the presence of sunlight when hydrocarbons react with nitrogen dioxide (NO_2). The chemical formulas $NO_2+hy \rightarrow NO+O$, and $O+O_2 \rightarrow O_3$ show the formation of ozone given nitrogen dioxide and sunlight. The chemical formula $NO+O_3 \rightarrow NO_2+O_2$ shows the chemical reaction that destroys ozone. During the night when there is no photolysis NO_2 increases, then with the presence of sunlight O_3 concentrations increase resulting in a cyclic inverse relationship(see Figure 8).

FIGURE 2



The lower peninsula of Michigan has a variety of ozone levels that do not necessarily follow expectations for urban compared to rural areas (see Figure 2). As shown in Figure 2, the ozone in Michigan had the highest concentrations in southern Michigan according to a 1979-2005 climatology study. Traditionally, urban areas have higher levels of NO_2. Michigan has only small cities in the areas of greatest ozone concentrations.

Figure 3 shows that in 2012 Michigan had an unprecedented number of ozone action days[4]. Ozone Action Days occur when the air quantity is forecasted to be unhealthy (see Figure 4 for ozone concentrations). Air quality in Michigan was studied in depth over a forested part of the northern lower peninsula by PROPHET (The Program for Research on Oxidants: Photochemistry, Emissions, and Transport). Part of PROPHET indicated a correlation of clean air coming from the north and polluted air masses coming from the south[3].

FIGURE 3

Action! Days in 2012

Location	Year	Number	Dates
Ann Arbor	2012	21	5/24, 5/27, 6/10, 6/15, 6/16, 6/20, 6/26, 6/28, 7/2, 7/3, 7/4, 7/5, 7/6, 7/7, 7/13, 7/16, 8/4, 8/24, 8/25, 8/28, 8/31
Benton Harbor	2012	21	5/24, 5/27, 6/9, 6/10, 6/16, 6/20, 6/26, 7/2, 7/3, 7/4, 7/5, 7/6, 7/7, 7/13, 7/16, 8/4, 8/24, 8/25, 8/28, 8/31
Detroit	2012	21	5/24, 5/27, 6/10, 6/15, 6/16, 6/20, 6/26, 6/28, 7/2, 7/3, 7/4, 7/5, 7/6, 7/7, 7/13, 7/16, 8/4, 8/24, 8/25, 8/28, 8/31
Eastern U.P.	2012	9	
Flint	2012	9	6/10, 6/15, 6/16, 6/20, 7/13, 8/4, 8/24, 8/25, 8/28
Grand Rapids	2012	25	5/24, 5/27, 6/9, 6/10, 6/15, 6/16, 6/19, 6/20, 6/26, 6/28, 7/2, 7/3, 7/4, 7/5, 7/6, 7/7, 7/13, 7/16, 7/18, 7/17, 8/4, 8/24, 8/25, 8/28, 8/31
Houghton Lake	2012	0	
Kalamazoo	2012	2	8/28, 8/31
Lansing	2012	1	8/28
Ludington	2012	18	5/24, 5/27, 6/9, 6/10, 6/15, 6/16, 6/20, 6/26, 7/2, 7/3, 7/4, 7/5, 7/6, 7/13, 7/16, 8/24, 8/25, 8/30
Saginaw	2012	0	
Traverse City	2012	0	

FIGURE 4

Air Quality Index (AQI) Pollutant Breakpoints for Ozone & Fine Particles

AQI value	Category	Ozone 1-hour (ppm)	Ozone 8-hour (ppm)	$PM_{2.5}$ ($\mu g/m^3$)
0 - 50	Good	-	0.000 - 0.059	0.0 - 12.0
51 - 100	Moderate	-	0.060 - 0.075	12.1 - 35.4
101 - 150	Unhealthy for Sensitive Groups	0.125 - 0.164	0.076 - 0.95	35.5 - 55.4
151 - 200	Unhealthy	0.165 - 0.204	0.096 - 0.115	55.5 - 150.4
201 - 300	Very Unhealthy	0.205 - 0.404	0.116 - 0.374	150.5 - 250.4
301 - 500	Hazardous	0.405 - 0.604	Above 0.371; 1-hour ozone would be used for AQI calculation.	250.5 - 500.4

ppm = parts per million.
$\mu g/m^3$ = micrograms per cubic meter

To investigate ozone levels across the state, ground station data was collected. Nine ground stations were chosen: Frankfort, Houghton Lake, Harbor Beach, Holland, Lansing, Port Huron, Coloma, Tecumseh, and Detroit. Ground station data of O_3 and NO_2 were analyzed to see where there is a build up ozone or where the inverse relationship does not follow the normal daily time scale. After identifying interesting events then trajectories were used for a correlation between air mass, movement and ozone concentration movement. Satellite data was analyzed to see the overall ozone and NO_2 concentrations.

Michigan Ground Station Locations (1-Frankfort, 2-Houghton Lake, 3- Harbor Beach, 4-Holland, 5-Lansing, 6- Port Huron, 7-Coloma, 8-Tecumseh, 9-Detroit)

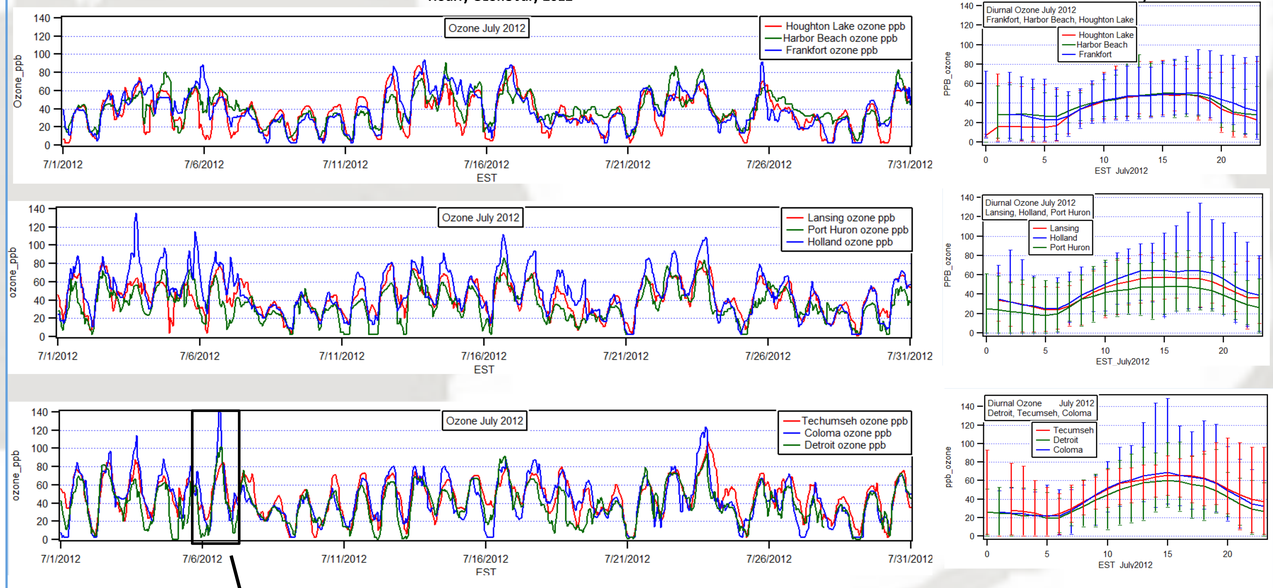
REFERENCES

1. www.airdata.epa
2. Raloff, Janet. "Ozone raises cardiovascular risk: pollutant triggers changes that can hike heart attack risk." *Science News* 28 July 2012: 10. *Gale Power Search*. Web. 27 Aug. 2013.
3.Cooper O.R., Moody J.L., Thornberry T.D., and M.A. Carroll, PROPHET 1998 meteorological overview and air-mass classification, *J. Geophys. Res.,* 106, 24,289-24,299, 2001.
4.http://www.deqmiair.org/actionday.cfm
5.http://www.michigan.gov/documents/deq/deq-aqd-aqifacts_273090_7.pdf
6.www.mynasadata.larc.nasa.gov
7.http://www.geo.sunysb.edu/ess-workshops/lesson-plans.html

Michigan July 2012

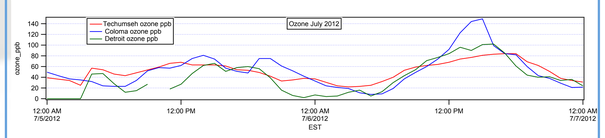
Below are the graphs of the hourly ozone and the diurnal ozone for July 2012 at the nine stations. The largest maximum ozone concentrations occur in the three western small cities of Frankfort, Holland, and Coloma (blue lines in the graphs). The lowest minimum ozone concentrations occur in the two eastern large cities of Detroit and Port Huron (green lines). The largest maximums occur in Coloma (southwest Michigan). The ozone diurnal graphs show that the ozone concentration increases throughout the day with large maximum values for the southern cities. The diurnal graphs also show that the average hourly ozone is the same going horizontally across the state with the most diversity occurring across the middle of Michigan. The three southern cities have similar averages and all have greater hourly averages then northern cities.

Hourly Ozone July 2012 | **Diurnal Ozone July 2012**



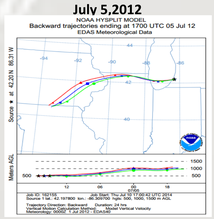
Coloma Ozone Event

The graph below shows an ozone event that happened in Coloma on July 6, 2012.

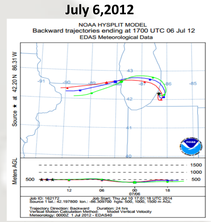


Below are the backward trajectories for Coloma. The air masses were transported across Lake Michigan from the Chicago area.

Backward Trajectory for Coloma July 5,2012

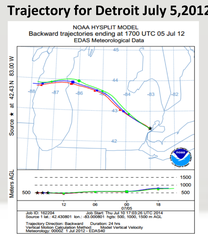


Backward Trajectory for Coloma July 6,2012

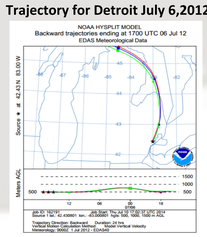


Below are the trajectories for air masses moving into Detroit at the same time period. Notice the air masses are moving in from the north on July 6, 2012.

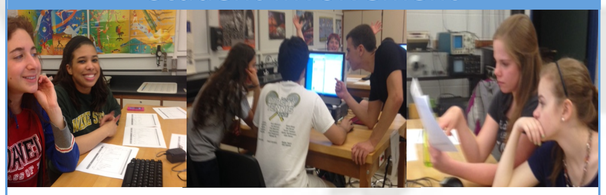
Trajectory for Detroit July 5,2012



Trajectory for Detroit July 6,2012

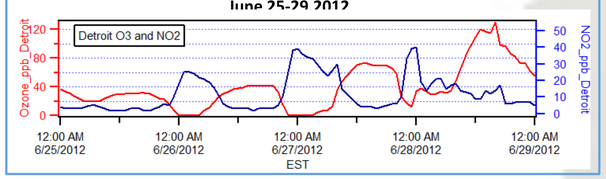


Student Involvement



Small groups of AP Physics C students (N=56) were provided time series graphs of NO_2 and O_3 for one of the nine stations (see Figure 5). They investigated nighttimes when the conversion between the gasses was incomplete. Students also looked for when the ozone started at zero then built up over the course of three days. After identifying an interesting event, the students investigated the relevant satellite data and performed trajectories.

Figure 5: Time Series Ozone (red) and NO_2 (blue) Detroit June 25-29 2012



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Examples of Student Work

Looking at the satellite data gave the students an overall picture of O_3 over the state of Michigan (Figure 2). The time series ground data made it possible for students to see the daily inverse relationship of NO_2 and O_3 (Figure 5). Figure 5 is an example of the ozone concentrations increasing but not due to an increase in NO_2. The tropospheric column NO_2 data matches with the ground station data, both showing higher levels on June 29,2012 than on June 25,2012 (Figures 6,7 and 8). The students also observed the blanks that occur in satellite data as the satellite passes over the surface of the Earth and measures a strip of data that can be obscured by clouds. Trajectories and ground station data supported that air masses from the west brought higher NO_2 and wind coming from the north brought clean air masses into the area.

Figure 6: OMI Tropospheric Column NO_2 June 25, 2012

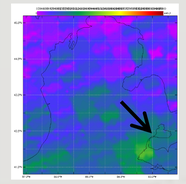


Figure 7: OMI Tropospheric Column NO_2 June 27, 2012

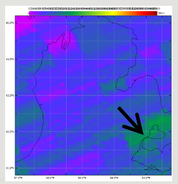
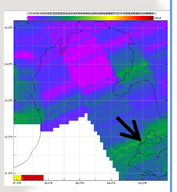
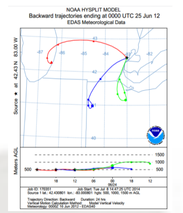


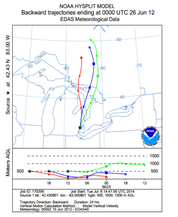
Figure 8: OMI Tropospheric Column NO_2 June 29,2012



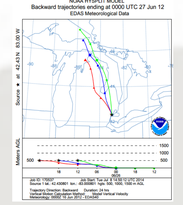
Backward Trajectory June 25,2012



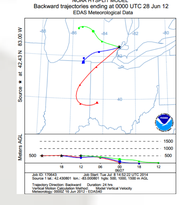
Backward Trajectory June 26,2012



Backward Trajectory June 27,2012



Backward Trajectory June 28,2012



Conclusions

The ozone climatology data gave an overall picture of ozone for the state of Michigan from 1979-2005 (see Figure 2). This data indicated that the highest concentrations of tropospheric ozone were in the southern part of the state. The diurnal ozone graphs for the state indicate maximums on the southwest side. The small southern western city of Coloma had significant ozone events in the summer 2012 larger than ozone events that occurred in the large city of Detroit on the eastern side of the state. The events explored by the students continued to support that clean air masses move into Detroit from the north while dirty air masses move in from the west. The second year of this study could include further evaluation of specific events. Including more trajectories and wind direction for the nine stations across the state for the same event to track the dirty or clean air masses and possible point of origin.